ONLINE MODAL IDENTIFICATION OF STRUCTURES BY NATURAL GRADIENT ALGORITHM

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Recently, blind source separation (BSS) methods have attracted considerable attention in modal identification and health monitoring of structures. BSS methods recover a set of independent sources from a mixture of output measurements without any prior information about the source signals or the mixing process.

Traditional BSS algorithms are batch-based which use all data in each step, and these algorithms require large storage capacity. Therefore, they are not suitable for online states. In this paper, an adaptive blind source separation technique, natural gradient algorithm (NGA) (Amari, 1998) is introduced to overcome the mentioned disadvantage within the structures. The NGA algorithm updates the un-mixing matrix for each step. With characteristics such as the need for little data, lower computational complexity, small storage capacity and lower analysis time the NGA algorithm is more suitable in civil engineering applications, especially in online structural identification. The efficiency of the proposed method is investigated with some synthetic examples.

Consider n unknown, statistically independent source signals $\mathbf{S}(t) \in \mathrm{R}^{m\times n}$ mixed by an unknown mixing matrix $\mathbf{A} \in \mathrm{R}^{m\times n}$, therefore, m mixed signals $\mathbf{x}(t) \in \mathrm{R}^{m}$ are observed according to:

$$\mathbf{x}(t) = \mathbf{AS}(t) \tag{1}$$

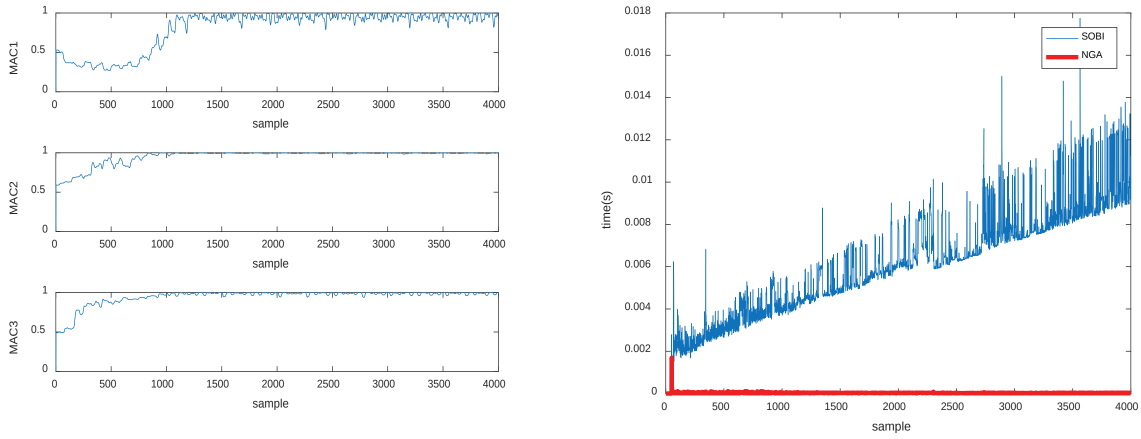
where t is the time index. For ease, it is assumed that the number of sources matches the number of mixtures, i.e. m = n. The main problem of blind source separation is then to estimate the realizations of the original source $\mathbf{S}(t)$ and the mixing matrix $\mathbf{A}(t)$ only using the observed signals $\mathbf{x}(t)$. This is equivalent to estimating the un-mixing matrix $\mathbf{W}(t)$. Then, the output signals can be obtained by $\mathbf{y}(t) = \mathbf{W}(t)\,\mathbf{x}(t)$, where $\mathbf{y}(t)$ represent the estimated sources. The focus of this paper is the NGA whose separating matrix updates equations can be generalized as follows:

$$\mathbf{W}(t+1) = \mathbf{W}(t) + \mu\left[\mathbf{I} - f\left(\mathbf{y}(t)\right)\mathbf{y}^{T}\right]\mathbf{W}(t) \tag{2}$$

where $f(\mathbf{y}(t))$is a vector of nonlinearly-modified output signals. For a linear, classically damped, and lumped-mass n-degree-of-freedom (n-DOF) structural system, responses can be written in terms of vibration mode expansions. X=Φq which is similar to Equation (1), where $\mathbf{\ddot{O}} \in \mathrm{R}^{n\times n}$ and $\mathbf{q} \in \mathrm{R}^{n}$ denote the modal matrix and modal coordinate, respectively. Therefore, when the modal coordinates are mutually uncorrelated, the modal identification of structures can be formulated as a BSS problem.

In order to show the efficiency of the proposed algorithm in modal analysis, numerical simulation is carried out on a simple 3-story shear building with mass proportional damping. For simulation, it is assumed that $m_1 = 3.0$, $m_2 = 1.5$, $m_3 = 1.0$ and $k_1 = k_2 = k_3 = 1.0$, the damping ratios are $\zeta_1 = \zeta_2 = \zeta_3 = 0.1\%$. To measure the correlation between the vibration modes and NGA modes the modal assurance criterion (MAC) is used (Maia and Silva, 1997). Figure 1-a shows convergence of MAC values to the unit, by increasing samples for free vibration.

Figure 1-b compares the solving time and computational performance of NGA to the SOBI in structural SI. According to Figure 1, NGA performs effectively in identification of mode shapes. Besides, it requires very little time for separation. The simulation results demonstrate the effectiveness of the NGA algorithm in on-line structural modal identification.



(a) (b)

Figure 1. (a) Time evolution of MAC values for free vibration 3-DOF. (b) Compares the solving time and computational performance of NGA to the SOBI in structural SI.

REFERENCES

Amari, S. (1998). Natural gradient works efficiently in learning. *Neural Computation*, *10*(2), 251-276.

Maia, N.M.M. and Silva, J.M.M. (1997). *Theoretical and Experimental Modal Analysis*. Research Studies Press, Taunton, Somerset, UK.